PATENT SPECIFICATION

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COMPLETE SPECIFICATION

Improvements in and relating to Devices for Detecting Magnetic Metal

Communicated from abroad by ILLINOIS TESTING LABORATORIES, INC., a corporation of the State of Illinois, of 420, North La Salle Street, Chicago, Illinois, United States of America.

I, EDWARD LLOYD FRANCIS, a British subject, of Jessel Chambers, 88—90, Chancery Lane, London, W.C.2, do hereby declare the nature of this invention and in what manner the same is to be performed to be particularly described and ascertained in and by the following statement:—

The present invention relates to metal detection systems, and while it is particularly concerned with devices for detecting the movement and therefore the presence of weapons, such as guns, knives or the like in banks, penal institutions, etc., and tools, such as files, saws, etc. in industrial establishments or penal institutions, the devices described herein have many industrial applications and may be used for detecting the movement and therefore the presence of magnetic metal under many different conditions.

According to the present invention a device for detecting a movement of magnetic metal comprises, in combination, a permanent magnet with a pair of coils, said coils being located to embrace parts of said permanent magnet and being oppositely connected so that the electro-motive forces generated in said coils by stray magnetic effects from static or like field disturbances will be counterbalanced. The arrangement is such that the movement of a magnetic body relative to the lines of magnetic force, comprising the field of said permanent magnet, will cause said lines of force to cut the coils and induce an electro-motive force, which by means of suitable connecting circuits and, if necessary, amplifying means, is adapted to operate any suitable indicating means.

According to one specific embodiment of the device used for detecting the presence of magnetic metal on the body of a person entering a building or room the said permanent magnets are mounted in a door frame, one series of said magnets along one side of said frame and another series mounted in the frame opposite to said first series, and a plurality of units of insulated wire arranged along said frame on each side.

Other objects and advantages of the invention will be apparent from the following description and the accompanying drawings, in which similar characters of reference indicate similar parts throughout the several views.

Referring to the drawings,

Fig. 1 is a vertical elevational view of the magnets and coils housed in a framework surrounding a doorway, for the purpose of detecting the movement of magnetic metal through the doorway, or within the effective range of the localized field surrounding the doorway, parts being removed from the door frame to expose the magnets and coils;

Fig. 2 is an elevational view of one edge of the doorway, partially broken away to show the interior structure of the arrangement of Fig. 1;

Fig. 3 is a fragmentary elevational view of the arrangements for supporting the magnets of Fig. 1, with the coils and enclosing cover boards removed;

Fig. 4 is a fragmentary sectional view taken on a plane passing through the axis of the coils, showing the magnets in elevation with their supporting structure;

Fig. 5 is a wiring diagram for a metal detection system, utilizing magnets and coils of the type shown in Figs. 1 to 4;

Fig. 6 is a plan view of a detecting device mounted directly beneath a conveyor belt for industrial use, such as, for example, to show the presence of magnetic metal in candy, carried by the conveyor belt;

Fig. 7 is a side elevational view of the arrangement of Fig. 6;

Fig. 8 is a wiring diagram, similar to that of Fig. 5, illustrating the use of the metal detection system, with an indicator or controlling device that does not require an amplifier;

Fig. 9 is a transverse, sectional view, taken through a magnet and coil arrangement, mounted on a shaft, and adapted to be rotated beneath a conveyor belt of

the type of Fig. 6, for the purpose of increasing the electrical effect where the movement of the belt is very slow, by moving the magnets and coils at a predetermined rate of speed;

Fig. 10 is a front elevational view of the rotating coil type of metal detection device of Fig. 9;

Fig. 11 is a sectional view of another arrangement for the magnets and coils for a device similar to Fig. 10, in which the magnets are so arranged in staggered relation as to ensure detection of a moving particle of magnetic metal on the belt;

Fig. 12 is a sectional view of the arrangement of Fig. 11;

Fig. 13 is a plan view of another modified form of movably mounted detector coils, arranged to rotate on a disc, and about an axis at right angles to the plane of the conveyor belt;

Fig. 14 is a side elevational view, in partial section, of the arrangement of Fig. 13;

Fig. 15 is a vertical elevational view of a highway provided with a metal detection device permanently mounted therein in such a manner as to occupy a minimum amount of space in the highway;

Fig. 16 is a plan view of the arrangement of Fig. 15;

Fig. 17 is a vertical sectional view of another arrangement of metal detection coils and magnets of the type of Figs. 1 and 2, mounted in a highway;

Fig. 18 is a plan view of the arrangement of Fig. 17, showing the most sensitive type of magnets and coils, capable of giving a metal detection impulse merely upon the passage of a small vehicle, such as a baby buggy, tricycle, or the like, over the metal detection device;

Fig. 19 is a vertical sectional view of another relatively small metal detection arrangement of magnets and coils, which also occupies a minimum amount of space in the highway, and which can be made sufficiently sensitive so that the metal detection electrical impulse will be produced when an automobile or the front axle of an automobile passes over the device;

Fig. 20 is a top plan view of the arrangement of Fig. 19, with the cover plate removed;

Fig. 21 is a plan view of a highway installation utilizing devices of the type of Figs. 15—20 for the purpose of control of the traffic control lights;

Fig. 22 is a vertical sectional view of the installation of the type shown in Fig. 21, the section being taken on the plane of the line 22—22 of Fig. 21;

Fig. 23 is a plan view of a safety arrangement for banks or similar institutions, for the purpose of effecting a detection of the presence of weapons of magnetic metal and for securing a photograph of the bearer for the purpose of identification of the bearer, in the event of any unlawful use of the weapon, after passing through the chamber;

Fig. 24 is another plan view of a metal detection chamber, for the purpose of detecting the presence of weapons having magnetic metal and for effecting a capture of the bearer, by means of interlocking doors, whenever the bearer carries such weapons;

Fig. 25 is a vertical elevational view of a surgical probing instrument, for the purpose of finding broken points of hypodermic needles, etc., in the flesh of a patient, by means of magnetic metal detection;

Fig. 26 is another elevational view of a similar surgical probing instrument, which is provided with a small, dense, and concentrated or local field, for the purpose of detecting the proximity of a broken hypodermic needle in the flesh of a patient;

Fig. 27 is an elevational view, in partial section, to show the internal coils and magnet of a metal detection instrument, which may be used on the surface of the body of a person, for the purpose of locating magnetic metal in the body, before taking X-ray pictures, so that the X-ray may be most effectively used, and for locating metals in emergencies, such as, for example, where there may be a possibility of suffocation.

Referring to Figs. 1 to 5, these are views of an arrangement for detecting the presence of magnetic metal due to the movement of the metal through a doorway.

Fig. 5 is a wiring diagram and will, therefore first be described. In the diagram 50 indicates an electrical indicator which may be an electric bell, a lamp, a galvanometer, or any two or all three of these indicators.

The conductors 51, 52 lead to the indicator 50 from the output of the amplifier 53, which may consist of any suitable electronic amplifier for amplifying the relatively weak signals or electrical impulses produced as a result of the movement of the magnetic metal, and producing an electrical voltage and current in the device 50 sufficient to produce the indication desired.

In other embodiments of the invention, such as, for example, Fig. 8, the amplifier 53 may be wholly omitted, and a galvanometer 54 may be used, with or without

any other indicators, visual or audible.

The input leads 55, 56 from the galvanometer of Fig. 8, or from the amplifier of Fig. 5, are connected to the coils 57—61. The coils 57—61 are without any energization and are preferably similar in their winding, resistance, inductance, and capacity; that is, in their electrical characteristics. Thus, each coil will have a lead 62 from the innermost turn and a lead 63 from the outermost turn. These leads are preferably connected in series and in such a manner that the effects produced in the coils counter-balance each other for each magnet.

The coils 57—61 are preferably flat, pancake type coils, thereby spreading the turns of wires over a greater area and enabling me to cover substantially all of the length of a doorway from the top to the bottom with turns of wire. The substantially even distribution of the turns over the inner area of the door frame facilitates a substantially uniform metal detection effect and sensitivity.

The coils 57—61 are arranged so that each coil (excepting the end coils 57, 61) has its centrally located aperture 64 about the two poles of two adjacent permanent magnets. The detector includes a plurality of permanent magnets 65—69, and the magnets are preferably each provided with the relatively short legs 70, 71 and the relatively long yoke 72.

The length of the yoke 72 bears a direct relation to the width of the doorway, in order to secure a substantially uniform field. In other words, the distance between the ends of the poles on the legs 70, 71 should be greater than half the width of the doorway shown in Fig. 1.

The magnets 65—69 are permanent magnets, and preferably have the legs 70, 71 at right angles to the yoke 72. These permanent magnets are arranged with their yokes 72 extending in substantially a straight line, and the like poles of the magnets are adjacent each other. Thus, the magnets are alternately reversed in direction, so that the two north poles will always be together and the two south poles will always be together. Otherwise, the tendency would be to decrease the external field of the magnet due to the direct passage of flux from one pole to an opposite pole, if they were in contact with each other.

The coil 61 thus embraces a north pole, while the coil 60 embraces two south poles. The coil 59 embraces two north poles, the coil 58 two south poles and coil 57 a north pole. The outer leads of adjacent coils 60 and 61 are connected together by a conductor 63, and the inner leads of the adjacent coils 60 and 59 are connected together by a conductor 74. Thus the outer leads of two coils 61 and 60 are connected together, and the two coils 60 and 59 have the inner leads connected together, and so on, thereby automatically reversing the connections of the coils. The coils on any one magnet as, for example, the coils 58, 59 on the poles of the magnet 67, are reversed in direction so that their effects are counter-balanced.

This is a very important feature of the invention, as this counter-balancing of the coils prevents any electrical impulses in the system due to ordinary static. The static from the spark of an opening switch would otherwise produce an electrical impulse, but such static effects are wholly eliminated or reduced by the counter-balanced connections of the coils, and only local effects, due to the distortion of the magnetic field, produced by the magnets 65—69, produce any effective impulse in the coils.

The magnets and coils of Fig. 5 may be arranged in a number of different ways, to effect a detection of metal. For example, only one magnet may be utilized, with its coils so connected when the magnet is to be brought close to the metal to be detected such as, for example, in the use of a hand operated magnet which is passed over the body of a person suspected of carrying weapons. The local field of the magnet is thus brought into juxtaposition with the locations in which it is suspected that the metal is present, and the movement of the magnet and coils covers a larger area over which detection is desired.

In other embodiments of the invention one or a few magnets may be located to provide a localized field such as, for example, over the top of a table or a portion of the table over which packages may be passed to determine whether they have in them articles including magnetic metal, such as, for example, weapons.

In every case it should be noted that the balancing of the coils and magnets is a static balance, rather than a dynamic balance, and there is no energization of the coils and no necessity to balance currents or voltages. Thus, there is no possibility of the coils heating up, and the power consumption is low, since power is consumed only by the amplifier when the amplifier is used.

Referring to Figs. 1 to 4, these are illustrations of the preferred mode of securing the magnets and coils in place in a doorway. The installation of these figures is that which has been used in penal institutions for metal detection with respect to visitors who have come to visit

the inmates, and are compelled to pass through the doorway 80 of Fig. 1.

In this embodiment of the invention the magnets are arranged in a similar manner on both sides of the door opening and extend to a point above the head of any person likely to pass through the doorway, and to a point slightly above the ankles of the person walking through the doorway. The purpose of keeping the lower magnet above the ankles or shoes of the person passing through the doorway is to prevent the actuation of the signal due to the metal nails which are usually used in shoes, or due to the metal arches or supporting members which may be present in the shoes.

Obviously, in case it were desirable, it would be feasible to extend the magnets all around the doorway, including the top and bottom, if desired; but in the particular installation the visitors are watched so that there is no possibility of their removing anything from their shoes, which are not subject to the metal detection, the magnets being arranged on opposite sides of the door in such a manner that the effective field of the right hand magnets extends to about the middle of the door, and that of the left hand magnets to the same point.

The lines which are drawn in a portion of Fig. 1 represent the lines of force from the magnets, and the normal or undisturbed condition of these lines is shown at the top of the figure. At the bottom of the figure there is a representation of the change in the lines of force which takes place when a member of magnetic metal is located in the field. It will be observed that the magnetic lines of force take the path of least resistance and tend to pass through the paramagnetic material, rather than through the air. This produces a concentration of the lines of force wherever a magnetic metal member is located.

As practically all weapons, such as knives, guns, etc., are made out of magnetic metal, such as iron or steel, it is possible to produce effective metal detection by merely detecting the presence or movement of magnetic metal. Furthermore, such weapons are usually disposed longitudinally of the body of the person carrying them, in order to conceal them more effectively; that is, a knife will extend along an arm or along the body, and thus present a considerable length vertically of the doorway, which also facilitates more effective detection of the presence of the weapon.

It should be noted that the mere presence of magnetic metal in the doorway does not produce any result so long as the magnetic metal is not moving. Thus, the presence of nails or proximity of other metal objects does not produce any signal as long as these parts are fixed with respect to the coils of the system.

However, in order to produce the most uniform magnetic field, the installation is preferably made by means of non-magnetic metal securing devices, such as brass screws or bolts, and glue is used in securing the wooden parts of the door-frame together.

When a member of magnetic metal moves through the doorway, the concentration of magnetic lines of force which pass through this metal member move with it. These lines of force then cut the coils which are disposed about the magnetic poles, and in cutting the coils produce an electro-motive force which is impressed upon the galvanometer directly or through the amplifier and produce a signal, ringing a bell, lighting a lamp, or both.

The metal having been detected upon the body of the person passing through the doorway, it is obvious that there is then valid ground for searching him or her and depriving him of any weapons. The person may then be caused again to pass through the doorway and only permitted to visit the penal institution after the metal detector has indicated the absence of magnetic metal by failure to produce any signal when the person passes through the doorway.

The doorway 80 is preferably arranged between the studs of a partition so as to present the appearance of an ordinary doorway; but, if desired, it may merely consist of a separate frame through which the person is compelled to pass. The magnets and coils are enclosed in a housing, and the housings at each side of the door being identical, only one will be described in detail.

Each housing comprises a board 81, which is provided with the side walls 82, 83, which may also serve as a part of the doorway. The frame member 81 is provided with a pair of vertically extending wooden strips 84, 85, which are glued to the board 81, and are spaced from each other by an amount which equals the width of the magnets 65—69. Thus these magnets are clamped at their opposite faces by the strips 84, 85.

The strips 84, 85 are of the same thickness as the thickness of the rods or bars of which the magnets are made, and thus the magnets may be clamped to the board 81 by a plurality of wooden cross strips 86—90 (Fig. 3). These strips 86—90 are secured in place by brass screws, with or without glue, and they hold the magnets

in the groove which is provided between the strips 84, 85.

The magnets being rectangular in cross section, they have flat outer surfaces which engage flatly against the board 81 and the strips 84, 85 and 86—90. Each end magnet 69 or 65 is also engaged by a wooden block 91, which is disposed between the strips 84, 85, and engages the endmost leg of the magnet. Since the magnets are forced against each other and there is a block at each end, they are securely confined in between the blocks and strips.

It is of the utmost importance that there should be no movement of the magnets with respect to the coils or of the coils with respect to the magnets. It is also desirable that there should be no movement of the coils and magnets with respect to the doorway, as otherwise a signal might be produced, due to the proximity of magnetic bodies which are not moving, but due to the movement of the system.

The wooden strips 84, 85 may also be further secured in place by a plurality of strips 92, which have cut-out portions for engagement with the strips 84, 85. These strips 92 may be pushed over against the strips 84 or 85 and screwed down with brass screws in such a manner that the portion over-lying the strips 84 or 85 effectively clamps those strips down to the board 81 and the shoulder at the end of the strip 92 forces the strip 85 over against the magnets.

The housing also includes a relatively thick wooden board 93, which fits in the open face of the box, and is provided with a plurality of apertures 94, suitably located to embrace the legs of the magnets.

Each of the apertures 94 also has a relatively shallow counterbore 95 communicating with it on the outer or face side of the board 93, and adapted to receive the pancake coils 57—61. These coils are of substantially disc shape, with a centrally located aperture for receiving the magnetic legs, and the coils are built up so that they fit tightly within the bores 95 and are flush with the outer surface of the board 93.

The board 93 is also secured in place by suitable screws, and supported by suitable spacing blocks 97, and the complete assembly is then covered by a board 98 of thin strong wood, such as, for example, plywood, which covers all of the magnets, coils, etc., completes the housing, and secures the coils 57—61 in the sockets 95.

Various other modes of securing magnets and coils in fixed position may also be used, but the foregoing is a preferred and effective method of making an installation.

The foregoing installation may be used not only in penal institutions, but in factories and other industrial establishments, to detect the presence of tools carried by workers. There is a considerable loss of tools due to theft by workers, and this can be wholly eliminated by the use of such a metal detector, which would cause a bell to ring or light to light when the worker passes through the doorway on his way out of the factory with a tool on his person.

Various other uses of the invention may be made, and I do not wish to confine myself to the particular examples given.

Referring to Fig. 6, this is a diagrammatic illustration of another form of the invention which may be used for detecting the presence of magnetic metal by virtue of its movement in solid, granular or other material, which might be carried upon a conveyor belt.

In this embodiment 100 indicates the conveyor belt, which passes above a metal detection unit 101, provided with a plurality of magnets 102, having suitable coils 103. The magnets and coils are fixedly secured to the supporting member 104, and are preferably arranged with the opposite legs 105, 106 offset or staggered with respect to each other in a direction transverse to the direction of movement of the belt.

The belt 100 shown in Figs. 6 and 7 may move upward or downward carrying material across the magnets 102, which are shown in plan, with their pole pieces projecting upward.

The magnets are arranged at an angle of substantially 60° to the direction of motion of the belt, and by means of this arrangement and a close spacing of the pole pieces or legs of the magnet, it is found that an intense or localized field may be produced above the belt, which will produce an impulse, due to the presence of very small pieces of metal, such as, for example, a piece of a needle or a nail, or any other small piece of metal.

The invention is of particular application in connection with the detection of metal in candy, as the presence of a small particle or piece of metal in candy is frequently the occasion for a damage suit against the candy manufacturer. When the metal detection unit, combined with or without an amplifier and an indicator, gives a suitable signal, then that batch of candy is taken out and either thrown away or worked over to find the metal particle, thereby eliminating the possibility of any metal in the finished product.

It should be noted that the area of the coils 103 is such as to practically occupy

all of the space available between adjacent magnets, so that the coils are almost touching, or, being insulated, they may touch each other. Also, the coils are connected as described with respect to Fig. 5, in such manner as to effect a counterbalance of the coils on each magnet.

In such industrial applications, I prefer to have the metal detection unit also control the operation of the machinery, such as the conveyor belt, so that when metal is detected the belt stops automatically.

It will be apparent from Fig. 6 that no object of magnetic metal could pass upward or downward on the figure, that is, horizontally across the magnets, without the lines of force, which are attracted to the object, cutting some of the coils of the magnets. The cutting of the coils by the lines of force takes place in three ways: First, the lines of flux cut the coils when they, in effect, jump from their normal position to the metal object. Second, the lines of force cut the coils when they move with the metal object across the coils. Third, they again cut the coils when the metal object passes out of the range of a certain line of force and the line jumps back to its normal position, away from the piece of magnetic metal.

It is, of course, understood that the action of the lines of magnetic force is that of a tension along the line and a repulsion transverse to the lines.

In some embodiments of the invention it will be found that the belt 100 moves so slowly that it is desirable to use other means to produce relative movement between the magnets and/or coils and the magnetic metal object which might be upon the belt in some commodity being transported on the conveyor belt.

In such case, an installation of the type of Figs. 9 and 10 will be useful. In this embodiment, there is a shaft 107 suitably supported in bearings for rotation about an axis which is parallel to the belt 100. The shaft may support a plurality of bar magnets 108, 109, the bar magnets being arranged at right angles to each other and being provided at each outer end with the coils 110.

Here again the coils should be connected so as to be balanced on each magnet and so that any static effects will be balanced out, as shown in Fig. 5. The coils are fixedly supported on the magnets, and the magnets fixedly clamped on the shaft 107 by suitable threaded members, with fiber washers 111 between the magnets so as to effect a clamping of the magnets without placing any such strain on the magnets as is likely to affect the magnetization.

The coils may all be connected in series, and a lead brought out at each end to a slip ring 112, 113, which is slidably engaged by a brush 114, 115, and connected to the amplifier or indicator.

The complete assembly may be enclosed in a non-magnetic cylinder 116, with non-magnetic end plates 117, such as a brass cylinder and brass end plates. This cylinder with its magnets may then be rotated at a constant rate of speed, thereby producing a rotating magnetic field, which in a similar manner is caused to be distorted by the presence of magnetic metal on the belt 100, which causes magnetic lines of force to cut the coils and produce electrical impulses.

The resulting electro-motive force will be alternating, and its frequency will depend upon the speed of rotation of the cylinder.

The polarity of the bar magnets or location of the poles should be as indicated on the sketch, so that the lines of flux extend from the end of each bar magnet to an opposite and adjacent pole on an adjacent bar magnet. For example, the cylinder may rotate at such a speed as to give 25 to 900 cycles per second. 25 cycles per second would require a rotation of 12½ revolutions per second.

Referring to Figs. 11 and 12, this is another arrangement for a rotating detector, in which permanent magnets 120 of U-shape are employed.

In this case each magnet is provided with an aperture 121 for passing a screw bolt 122, the aperture being located in the yoke parallel to the legs of the magnet. The shaft 123, which may be of non-magnetic material or magnetic material, is provided with threaded bores, and the threaded bores are rotated at equally spaced distances along the shaft, which has a square portion for supporting the magnets.

The bores are staggered helically, so that the magnets may be arranged as shown in Fig. 12, each magnet being at an angle of 90 degrees to the adjacent magnet and located one step farther along the shaft.

This arranges the poles of the U-shaped magnets helically on the shaft, and they are provided with the same coils 124 connected in the same way, to effect a counterbalance of the coils on one magnet, and connected in series with each other.

The housing of the device may be the same as described in Figs. 9 and 10, and the slip rings and brushes may be similar.

It should be understood that in each of these embodiments the representations of the coils 110 or 124 are merely diagrammatic, and the coils are of suitable size, as described with respect to Figs. 5 and 6, to

assure the cutting of the coils by distorted lines of force, whenever any small particle of magnetic metal is carried on the belt 100.

Referring to Fig. 13, this is another conveyor belt arrangement, in which the conveyor belt 100 is located above a disc-like housing 125 of non-magnetic metal, which is supported upon a vertical, rotating shaft 126.

In this case a plurality of magnets are arranged with their poles on radial lines, as shown, and each pole is provided with a coil 127, 128, of insulated wire, preferably located near the end of the pole, at the top, as shown in Fig. 14.

These coils are again connected in the same way, to effect a counter-balance, and the shaft is provided with a pair of slip rings, similar to those shown in Figs. 9 and 12, and brushes for taking off the voltage from the rotating disc.

The field extends across from the north poles to the south poles of each magnet, and also from the north poles to the south poles of adjacent magnets, and as this field is a rotating one, it does not matter whether there may be a neutral point at the center of the disc, since anything passing over the center of the disc in the direction of movement of the belt, as indicated will have to pass over some other part of the disc where the lines of force are cutting across directly.

Referring to Fig. 21, this is a wiring diagram of a highway installation, in which the number 130 indicates the control box, having suitable circuits, such as the electronic amplifier and relays for controlling the signal lights or illuminating lights. Numbers 131—134 indicate the usual " Stop " and " Go " lights, and the cables 135—137 extending from the control box 130 indicate the necessary plurality of conductors for controlling the lights.

The metal detection units are preferably so disposed in the road that they will be actuated only by vehicles approaching the lights on the right hand side of the road. 138 indicates a north and south extending road, while 139 indicates an east and west extending road. These roads intersect and, as illustrated, are four lane roads. Each road has one or more of my metal detection units, later to be described, disposed in the traffic lane, at a point spaced from the signal light, such as, for example, 50 or 100 feet. Thus the metal detection units 140 and 141 are in the highway 138 north of the intersection, and control the approach of vehicles toward the light 132.

In a similar manner, other metal detection units 142—147 are located in each part of the road, approaching the intersection on the right hand side of the road, so as to be actuated only by approaching vehicles, the left hand side of the road, extending away from the intersection, being always without detection units. Of course, it should be understood that where the law requires the driving on the left hand side of the road these conditions would be reversed.

The numerals 148—155 indicate appropriate cables, each having the necessary plurality of conductors leading from each metal detection unit to the control box.

It should be noted that the metal detection units may be sealed and entirely water-proofed, and with the present system there is practically no danger of voltage break-down, since the voltages carried are in the nature of microvolts.

The metal detection units used are preferably of the type disclosed in Figs. 15—20, in which the detection effect is sufficiently localized so that a signal or impulse will be given only by a vehicle which is actually in close proximity to the metal detection unit. Thus, vehicles passing north to the right of the units 140 and 141 will give no metal detection signal as long as they are in the right hand lanes. This is not true in some of the devices of the prior art where the metal detection impulse depends upon the earth's magnetic field or the residual magnetism of the metallic parts of the vehicle.

The metal detection signal may not only control traffic lights and vary the periodicity of the lights, so that where there is no cross traffic a car approaching the lights will be given the " Go " signal quite promptly, and will not be compelled to wait for the regular period of the lights, but such metal detection units and control circuits, according to the diagram of Fig. 5, may also be used for controlling electric advertising signs. Thus, a sign board may be disposed in the country and provided with suitable flood lights, the flood lights being controlled by relays, so that when a car approaches the sign the suitably located metal detection units, at the right hand side of the road, will give a signal which will control the turning on of the light and the sign will be illuminated as the car approaches.

Another suitably located metal detection unit beyond the sign may be arranged to turn off the light, or the light may be controlled by suitable relays and timing devices, so that it merely stays on for a predetermined length of time, in which case no other metal detection unit is needed to turn it off.

Referring to Fig. 15, this is an illustration of one form of metal detection unit.

It comprises a non-magnetic tubular housing, such as a lead pipe 160, within which is disposed a bar magnet 161, having the insulated wire coils 162, 163 disposed at each end.

This tube is closed at its upper and lower ends, and the extra space in the tube may be filled with initially plastic compound, such as wax, or compositions of wax and tar so there is no space for air and therefore no possibility of condensation in any open spaces.

The coils are again connected in reverse order, the innermost turn of one coil being connected to the innermost turn of the other, and the outermost turns being connected to the leads, which are contained in cables 148—155. This type of metal detection unit is disposed in a highway, such as a concrete road 164 and has the advantage that it occupies a minimum amount of space and requires only the formation of a drilled bore extending vertically in the highway. It is, therefore, easier to install in existing highways, and relatively easy to install as the highway is built.

It has the disadvantage that it may not be effective if there is an iron mass in the ground closer to the lower end than the metal parts of the vehicle are to the upper end.

A plurality of such units may be used at regularly spaced points across the traffic lane, or one such unit suitably located may be sufficient in certain installations.

Referring to Figs. 17 and 18, this is a modification in which the U-shaped magnet of the type shown in Fig. 5 is used. The magnet 70 is disposed with its legs 71, 72 extending upward and its coils 60, 61 at the upper ends of the legs, the coils being large, flat, pancake coils. It is enclosed in a non-magnetic brass or lead housing, which may be substantially rectangular in section and filled with compound which holds the coils and magnet in position.

The unit of Figs. 17 and 18 can be made sufficiently sensitive so that it will give an electrical impulse upon the passing of a baby buggy or tricycle over the unit. The vehicle in all of these devices must be located right above the unit, in order to give a signal, and a car on the other side of the highway has no effect.

Referring to Figs. 19 and 20, this is another modified form of metal detection unit for highways of the type illustrated in Fig. 21. In this embodiment the housing is long and narrow, and made of non-magnetic material. It includes a pair of permanent magnets 170, 171 arranged with the legs of the magnets extending upward and the similar poles adjacent each other in the middle.

The elongated solenoid coils 172, 173 are provided with the soft iron cores 174, 175, the axis of each of these coils being horizontal, and the ends of the cores being spaced from the poles.

Extra space in the unit is again filled with insulating compound, which holds the parts in place, in addition to the usual securing screws and bolts.

The coils here are again connected in such manner as to counter-balance each other, and these devices may be made of such sensitivity that a car or a front axle passing over the unit will give a signal impulse, but it will not be actuated by such a small vehicle as a baby buggy or a tricycle. This unit is again relatively easy to install, on account of its relatively small area and size.

Referring to Fig. 23, this is a diagrammatic illustration of a system using a magnetic metal detection doorway frame of the type of Figs. 1—4. In this embodiment the magnetic metal detection frame, or the collection of units 180, is arranged in a special chamber 181, the walls being indicated by 182—185. There is a doorway 186 in the wall 182 and a doorway 187 in the wall 184, each doorway being provided with a suitable door 188, 189.

The metal detection frame 180 is located just inside the doorway 186, so that a person passing through the chamber must pass through the frame. Located at a convenient corner 190 is a motion picture camera 191, with its lens suitably focused and the stop and shutter properly adjusted for the taking of motion pictures under a bright light, with which the chamber is continuously lighted.

The field of view of the camera is indicated by the dot-dash lines 192, 193, and the focus is such that it not only is suitable for the taking of the photograph of a party in the frame 180, but it also takes in the photograph the dial and hands of the electric clock 194 disposed on the wall 185. 195 indicates the control cables extending from the metal detection frame to the control box 196, which has a suitable amplifyng apparatus and controlling circuits. 197 indicates a conductor cable leading from the control box to an electric door lock 198. 199 indicates a conductor cable leading from the control box 196 to the camera, which is provided with a suitable relay for turning on the camera or for controlling an electric motor which drives the camera.

The operation of this system is as follows: The arrangement is intended to be used in a bank or similar institution for the detection and recording of the iden-

tities passing into the bank with weapons or other magnetic metals on their persons. During the course of the day numerous guards may pass in and out of the chamber, and the device may be arranged so that upon the pressing of a button it will fail to record when a guard passes through, or the guards may actuate the device in the usual way, due to the presence of their firearms. No attention would be paid to the photographs made of the guards unless it became important later on, but in the event of a robbery of the bank the arrangement shown in Fig. 23 would provide a positive identification of the criminals, in the following manner:

When a person carrying a gun, for example, passes into the frame 180, a magnetic metal detection impulse is produced by means of the magnets and coils, as described with respect to Fig. 1, and conducted by the cable 195 to the control box. This impulse is amplified, and by suitable circuits it turns on the camera 191, which runs for a few seconds and takes pictures of the individual. The picture also shows the face of the clock, which, being an electric clock, constantly shows the right time. In the event of a robbery, the film in the camera can be developed immediately and the pictures of the persons carrying guns, who passed through the chamber, will appear on the film.

The electric lock 198 is an auxilary feature, and it may be controlled also by the control box 196, so as to prevent persons bearing weapons from passing through the doorway 187, due to closure of the door 189, and locking by the lock 198 when weapons are present.

Referring to Fig. 24, this is another modified arrangement, in which each of the doors 188, 189 is provided with an electric lock 198, 198^1. The similar parts in these views have been given similar reference numerals. In this case the camera and clock are omitted, but the control box and locks 198, 198^1 are so arranged that they are interlocking. The relays are so arranged that the door 189 can only be opened after the door 188 has been closed, and the door 188 can only be opened when the door 189 is closed.

The operation of this system is as follows: A person passing into the chamber cannot pass directly through without going through the frame 180. If he carries weapons and passes through the frame 180, the door 188 will automatically close behind him, due to suitable springs or door checks. The control box and relays are so arranged that upon the presence of a metal detection impulse both doors are locked. Thus, the person carrying a weapon is locked within the chamber, which may be provided with suitable bullet-proof walls and inspection windows of bullet-proof glass.

Suitable arrangements for weapons controlling the interior of the chamber may be made or injection of tear gas, so as to subdue and disarm the person carrying the firearms.

If there is no metal detection impulse, the door 189 will open as soon as the person reaches it, and opens it, provided the door 188 has been closed.

In the event the door 188 is held open by an accomplice, to assure the escape of the person passing in first, the criminals will still not be able to penetrate into the bank, since the door 189, with its interlocking arrangement, cannot be opened.

Referring to Fig. 25, this is a view showing a surgical instrument embodying my invention. In this instrument there is a magnetic probing needle 200 carried by a non-magnetic handle, such as a wooden handle 201, and secured in place by a set screw 202, so that the projection of the sharp point 203 may be adjusted.

The magnetic needle 200 is surrounded by a pair of coils 204, 205, which are connected as shown in Fig. 5, and the leads in the cable 206 may be connected to a suitable galvanometer, as in Fig. 8, or to an amplifier and indicator, as in Fig. 5.

The device is most effective when the probing point 203 projects a minimum amount from the end of the coil 205. It is useful in locating broken hypodermic needles, the points of which are frequently broken off, as, for example, in the adipose tissue of a fat person.

The best indication is given when the point comes in contact with the broken and imbedded particle of the steel needle, thereby locating it and enabling the surgeon to determine where to cut to remove the needle.

Referring to Fig. 26, this is another modification of a surgical instrument, in which a U-shaped permanent magnet 210 is provided, having two probing points 211, 212. Two coils 213, 214 are provided, one on each leg, and they are oppositely connected, as shown in Fig. 5, the lead cable 215 being connected to the galvanometer or amplifier.

In this case a small, dense field is provided between the points of the needles, which is adapted to locate the embedded broken portion of a hypodermic needle between the points.

Referring to Fig. 27, this is an instrument to be used by surgeons and physicians on the surface of the skin, the instrument being passed over the skin to locate metal below the skin. It includes a non-magnetic handle 201 provided with

a non-magnetic housing 202 at one end, containing a bar magnet 203, one end of which comes to the face 204 of the non-magnetic housing.

The bar magnet 203 has a coil 205, 206 at each end, the turns on the coil being again connected as shown in Fig. 5, so as to effect a counter-balance. This instrument is used with the circuit of Figs. 5 or S for locating a piece of metal in the body near the surface in emergencies such as, for example, where there is a possibility of suffocation, or it is used for locating metal preliminary to the taking of an X-ray, so that the X-ray may be most effectively taken.

It will thus be observed that I have invented an improved metal detection system and a multiplicity of industrial and other applications of metal detection units of improved characteristics.

My metal detection system is characterized by a lack of heating of the coils, since there is no energy needed for the coil system, and by low power consumption, since power is only required for the amplifier where an amplifier is used. The system is balanced against stray field disturbances and is unaffected by the presence of metals not in motion. There are no currents or voltages to be balanced, and therefore no need for constant readjustment to preserve the balance. It is characterized by a stationary balance rather than a dynamic balance of currents or voltages.

So far as I am aware, prior to my invention there were no metal detection devices which were capable of eliminating the disturbances caused by static charges, distortion of the earth's magnetic field by heavy moving metal bodies, and electromagnetic waves sent out by D.C. machinery. The electromagnetic waves, for example, sent out by the starting or change of energization of a street car motor produced such electrical impulses in the prior art devices that false signals were caused and effective detection was impossible. Such a disturbance might be felt over a distance of half a mile.

It should be noted that where the coils of my system are stationary the device is primarily adapted for the detection of ferrous metals; where the coils are arranged for rotation the devices are adapted for the detection of the presence of any magnetic metal due to the action of eddy currents.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim is:—

1. A device for detecting a movement of magnetic metal comprising, in combination, a permanent magnet with a pair of coils, said coils being located to embrace parts of said permanent magnet and being oppositely connected so that the electro-motive forces generated in said coils by stray magnetic effects from static or like field disturbances will be counter-balanced.

2. A device for detecting a movement of magnetic metal comprising, in combination, a permanent magnet with a pair of coils, said coils being located to embrace parts of said permanent magnet and being oppositely connected so that the movement of a magnetic body relative to the lines of magnetic force, comprising the field of said permanent magnet, will cause said lines of force to cut the coils and induce an electro-motive force, connecting circuits, means for indicating the existence of said electro-motive force with or without means for amplifying the electro-motive force.

3. A device as claimed in claim 1 or 2, in which there is provided a plurality of permanent magnets fixed to a rotating shaft in proximity to a conveyor or belt.

4. A device as claimed in claim 1 or 2, in which there is provided a plurality of permanent magnets mounted on a support or in a frame.

5. A device as claimed in claim 1, 2 or 4, wherein said coils are relatively flat and wide in shape for the purpose of augmenting the electro-motive force induced in said coils by movement of a magnetic body moving in the field of the permanent magnet, said coils being located adjacent the poles of said permanent magnet.

6. A device as claimed in any of claims 1, 2, 4 or 5, provided with similar permanent magnets arranged so that the two similar poles of the two adjacent magnets are adjacent each other and embraced by a single coil, and the coils being connected in series.

7. A device for detecting a movement of magnetic metal, comprising a directive non-magnetic frame for directing the course of movement of the subject-matter of test in a predetermined test space, a number of permanent magnets carried in spaced relation to each other by said frame and having pole pieces located about the frame in such manner as to provide a substantially uniform magnetic field in said test space within said directive frame, a number of insulated wire coils carried by said frame and having the conductors of said coils substantially uniformly distributed along a boundary of said frame, said coils and magnets being fixedly secured against motion relative to each other, whereby any movement of a body of mag-

netic metal in said space causes a movement of lines of force of said magnetic field and a cutting of conductors of said coils and induction of an electro-motive force of predetermined intensity in said coils, and means for causing an indication of the presence of a body of magnetic material in the subject-matter of the test controlled by said electro-motive force, said magnets being provided with relatively short legs and long yokes, and having similar poles of adjacent magnets, adjacent each other, said coils embracing both said poles, and said coils being of pancake form, similarly constructed and adjacent coils being oppositely connected in series.

8. A device as claimed in any of the preceding claims, provided with an electronic amplifier for receiving the electrical impulses generated in said coils, and means connected to the output of said amplifier for producing a signal to indicate the presence of the magnetic body by its movement.

9. A device as claimed in claim 1 or 3, wherein said permanent magnets are of subtantially **U**-shape having an elongated yoke and relatively short legs.

10. A device as claimed in claim 3, wherein said permanent magnets are bar magnets arranged at right angles to each other on the rotating shaft.

11. A device as claimed in any of claims 1, 2, 3, 5, 6, 7 or 8, wherein said coils are characterised by a lack of energization and are arranged so that any magnetic body passing within the range of the field of said permanent magnet or magnets will produce an electrical impulse in said coils due to the movement of the magnetic body and the cutting of the coils by lines of magnetic force which move on account of the movement of said magnetic body.

12. A device as claimed in claim 11, mounted in a door frame, one series of permanent magnets being arranged along one side of said frame and another series mounted in the frame opposite to said first series, and a plurality of units of insulated wire arranged along said frame on each side.

13. A device as claimed in claim 3, 9 or 10, applied to a moving conveyor or belt, wherein each of said coils is of insulated wire, the coils embracing each magnet being oppositely connected with respect to the direction of the winding whereby the effect of static is eliminated, means being provided for rotating the shaft carrying the permanent magnets, with the poles coming into position adjacent said conveyor or belt, whereby the relative motion between the field of said magnets and a metallic body on said conveyor or belt causes a cutting of the coils by the flux of said magnets and the generation of an electro-motive force in said coils.

14. A device as claimed in claim 3, 9, 10 or 13, wherein the rotating shaft is provided with means for taking off the electro-motive force generated in the coils from the rotating parts of said shaft, and means for indicating the presence of said electro-motive force.

15. A device as claimed in claim 1, for detecting a movement of magnetic metal on a highway comprising, in combination, an enclosed waterproofed housing of non-magnetic material with a permanent magnet in said housing and having a pole located adjacent a surface thereof to be arranged flush with the surface of a highway and a pair of coils embracing said magnet, said coils being oppositely connected with respect to the direction of winding on said magnet.

16. A device as claimed in claim 15, wherein said magnet and coils are sealed in initially plastic compound in said waterproof housing to prevent the access of air and the possibility of condensation of moisture in said housing.

17. A device as claimed in claim 15 or 16, wherein the permanent magnet is a vertically arranged bar magnet having an upper and a lower coil, the former being disposed adjacent to the said surface of the housing arranged flush with the surface of the highway.

18. A device as claimed in claim 15 or 16, wherein the permanent magnet is a bar magnet arranged horizontally with its poles directed upwards, a coil embracing each pole and being arranged adjacent to said surface of the housing arranged flush with the surface of the highway.

19. A device as claimed in claim 15 or 16, comprising a plurality of permanent magnets, each disposed horizontally with its poles directed upwardly, each magnet having a coil which is also arranged horizontally and is provided with a soft iron core, the ends of which are spaced from the poles of the magnet.

20. A traffic signalling system for highways, comprising devices as claimed in any of the preceding claims 15 to 19, said devices being electrically connected to the signal lights of said system and arranged to control said lights.

21. Electric advertising signs, controlled by devices as claimed in any of the preceding claims 15 to 19.

22. A metal detection device arranged and adapted to operate substantially as described with reference to Figs. 1 to 5 or 8; Figs. 6 and 7; Figs. 9 and 10; Figs. 11 and 12; Figs. 13 and 14; Figs. 15 and

16; Figs. 17 and 18; Figs. 19 and 20; Fig. 23; Fig. 24; and Figs. 25, 26 and 27 of the accompanying drawings.

Dated this 17th day of January, 1939.

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Leamington Spa: Printed for His Majesty's Stationery Office, by the Courier Press.—1940.

Fig. 2

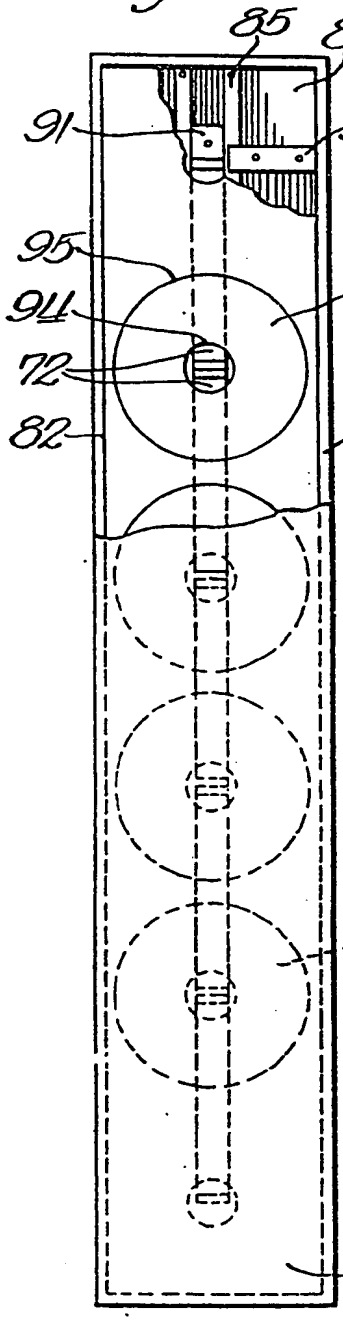


Fig. 1

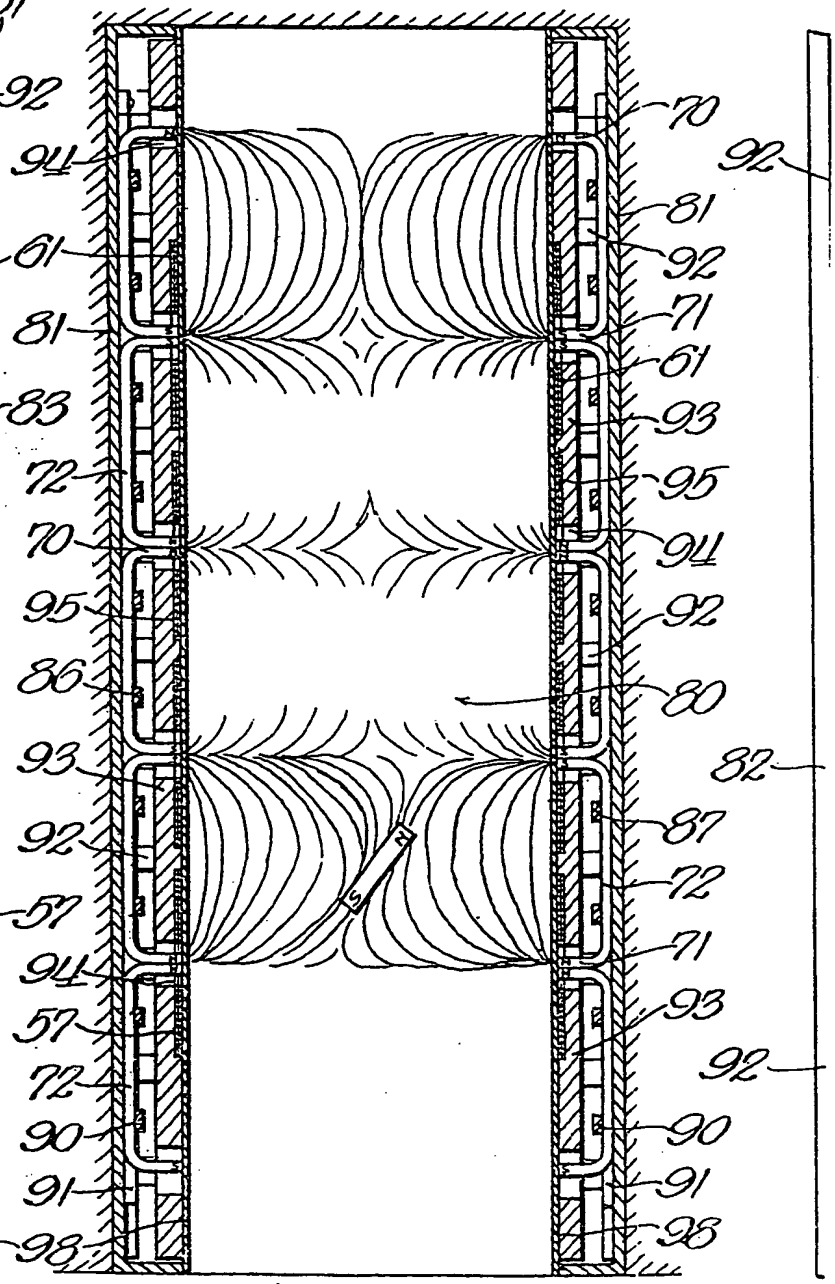


Fig. 3

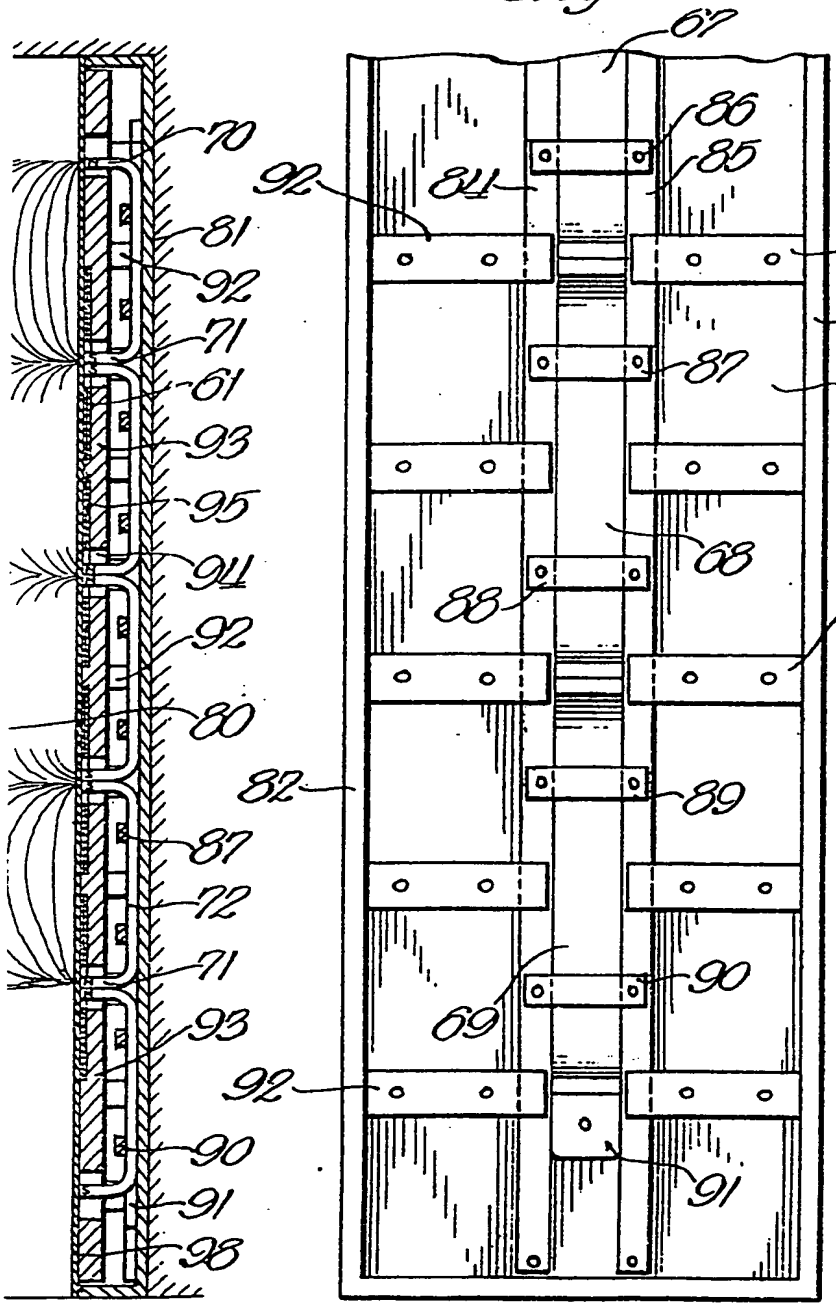
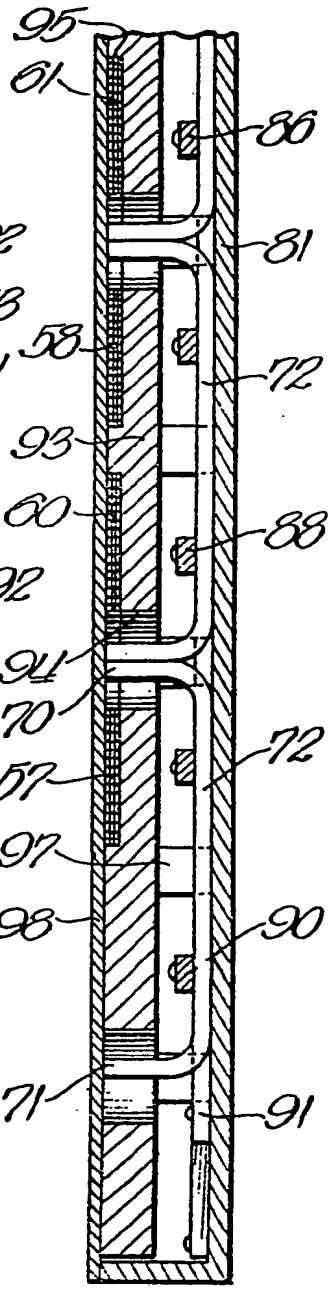


Fig. 4



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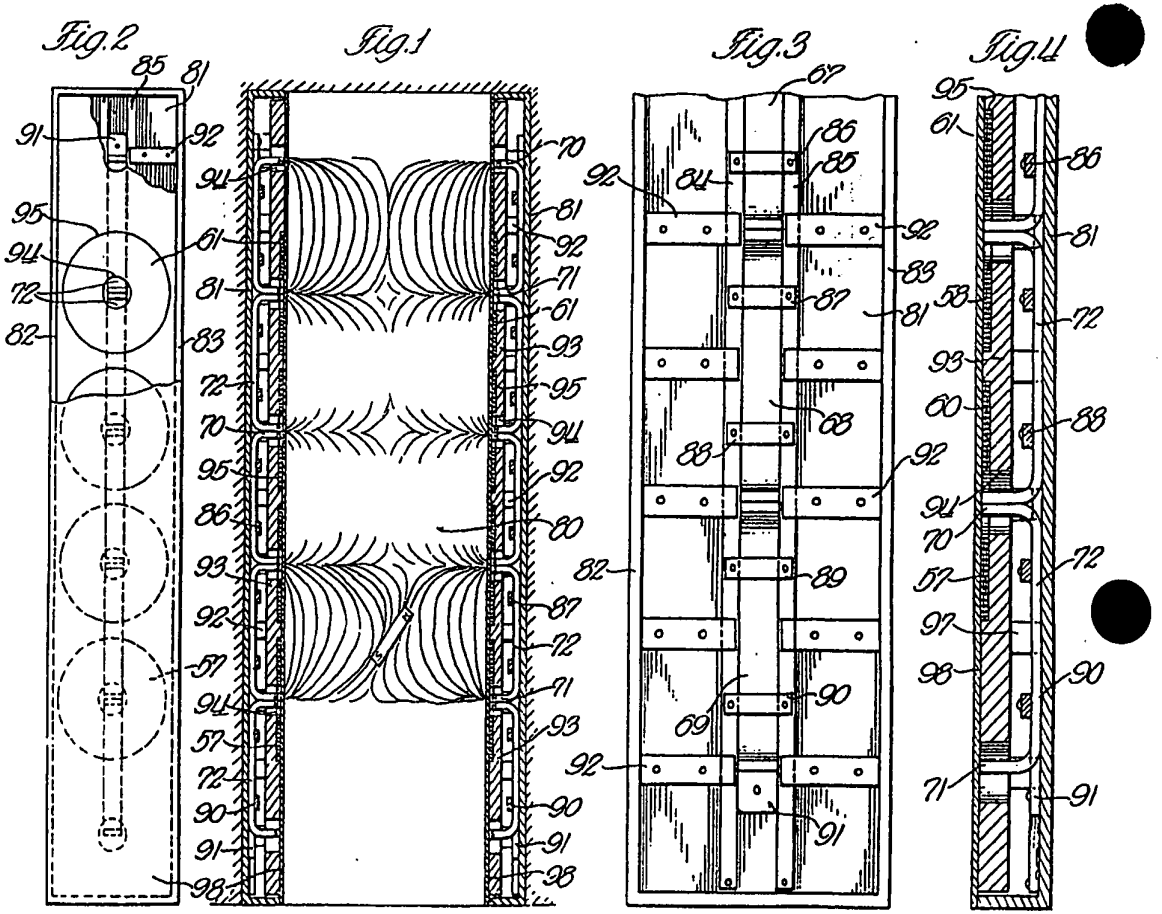

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Fig.5

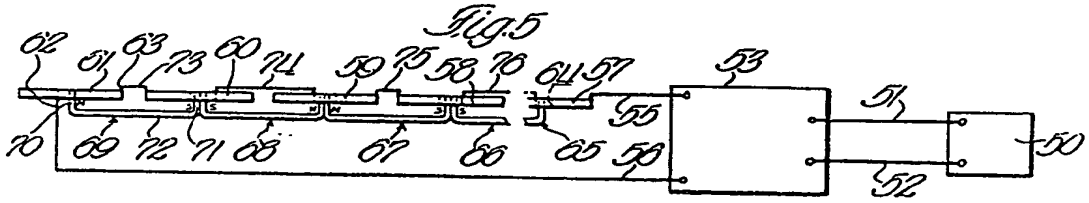
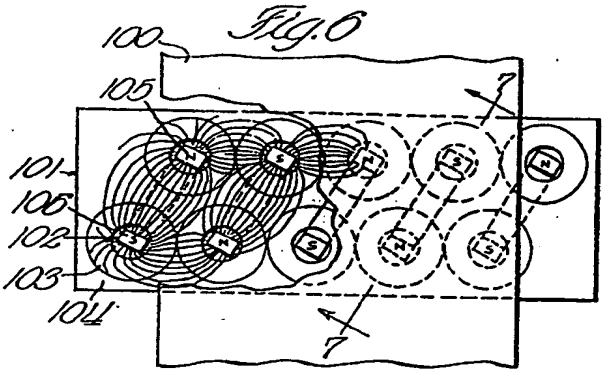


Fig.6



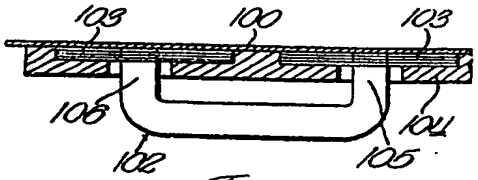


Fig.7

Fig.8

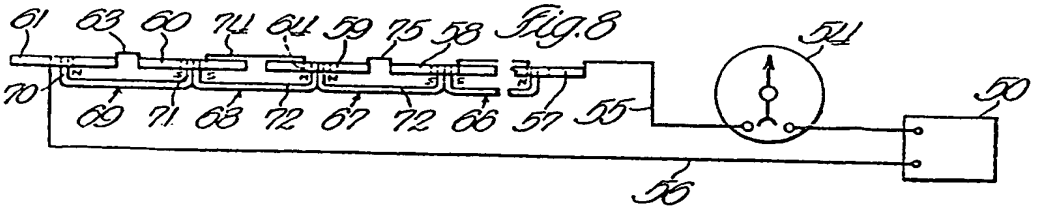


Fig.9

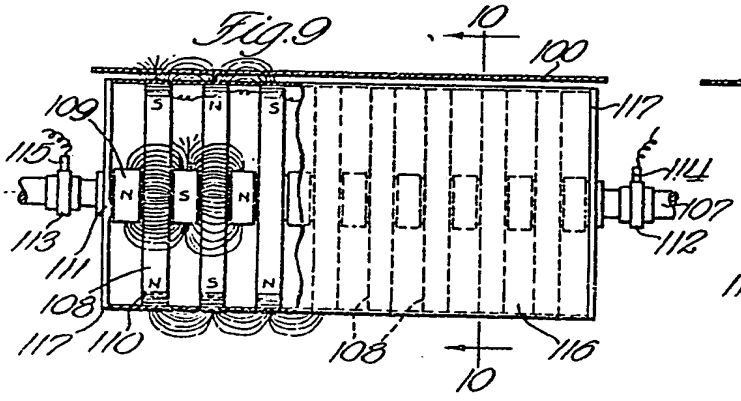
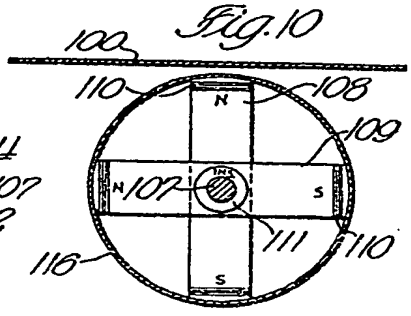
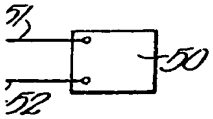
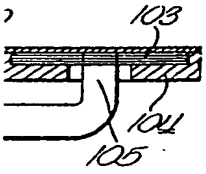


Fig.10







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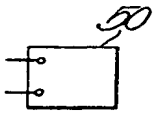


Fig. 10

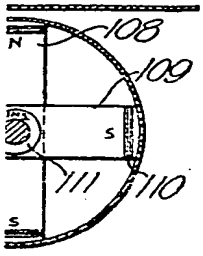


Fig. 12

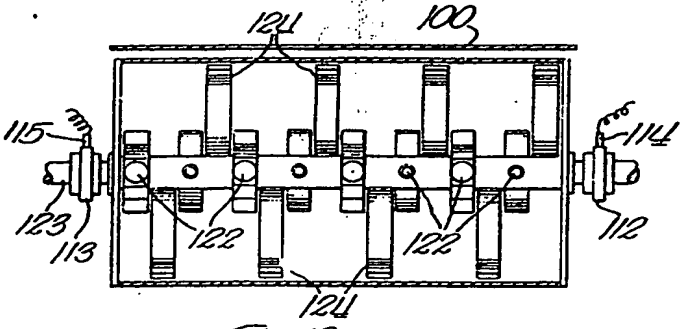


Fig. 11.

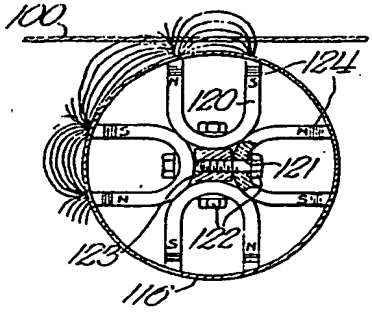
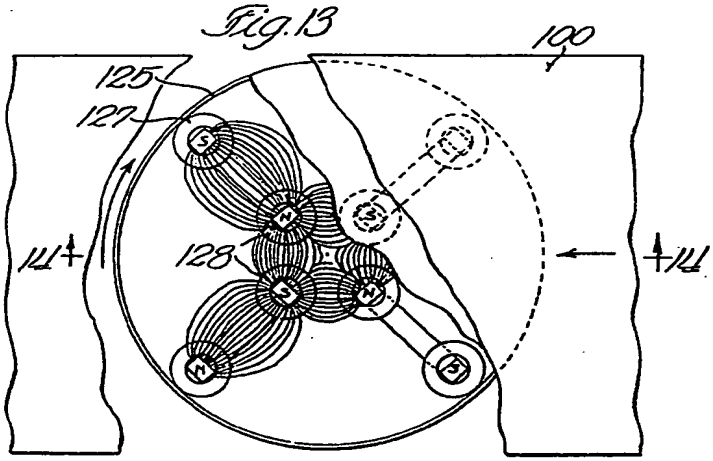


Fig. 13



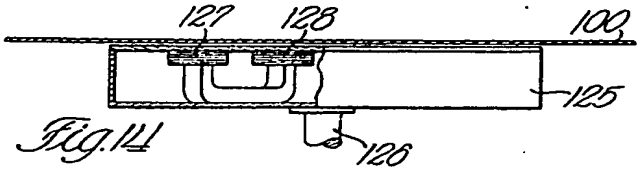


Fig. 14

Fig. 15

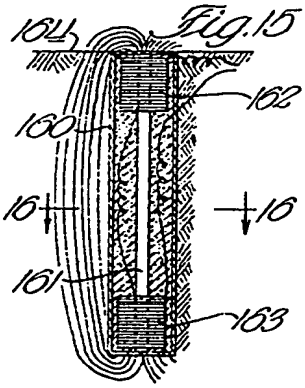


Fig. 16

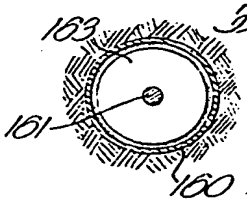


Fig. 18

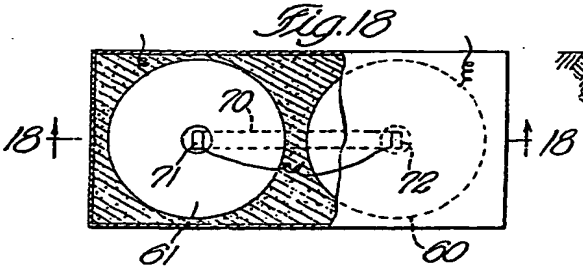
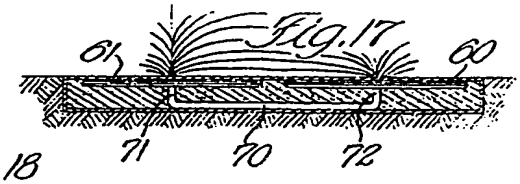


Fig. 17



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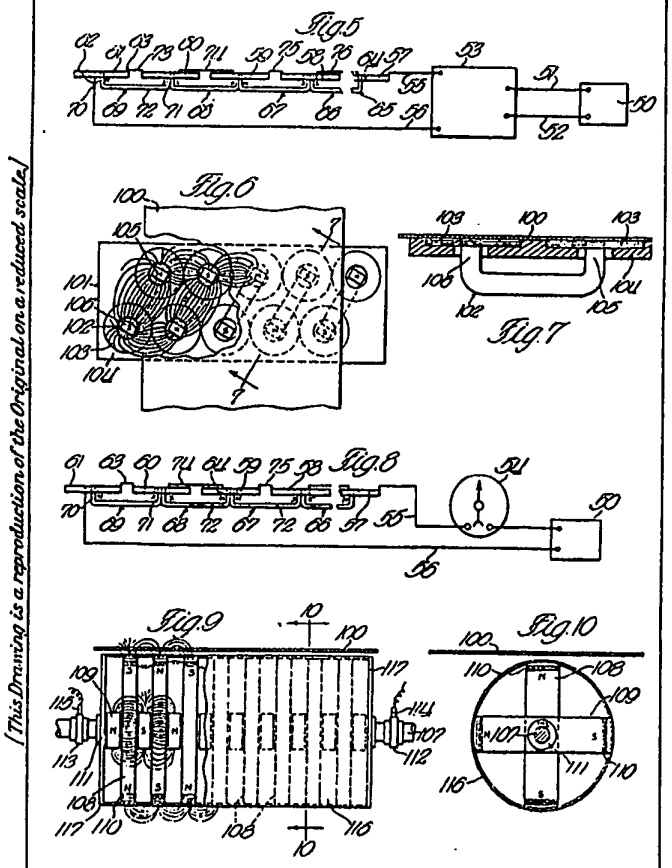

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Fig. 19

Fig. 20

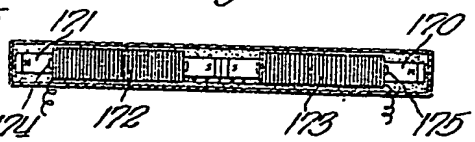


Fig. 21

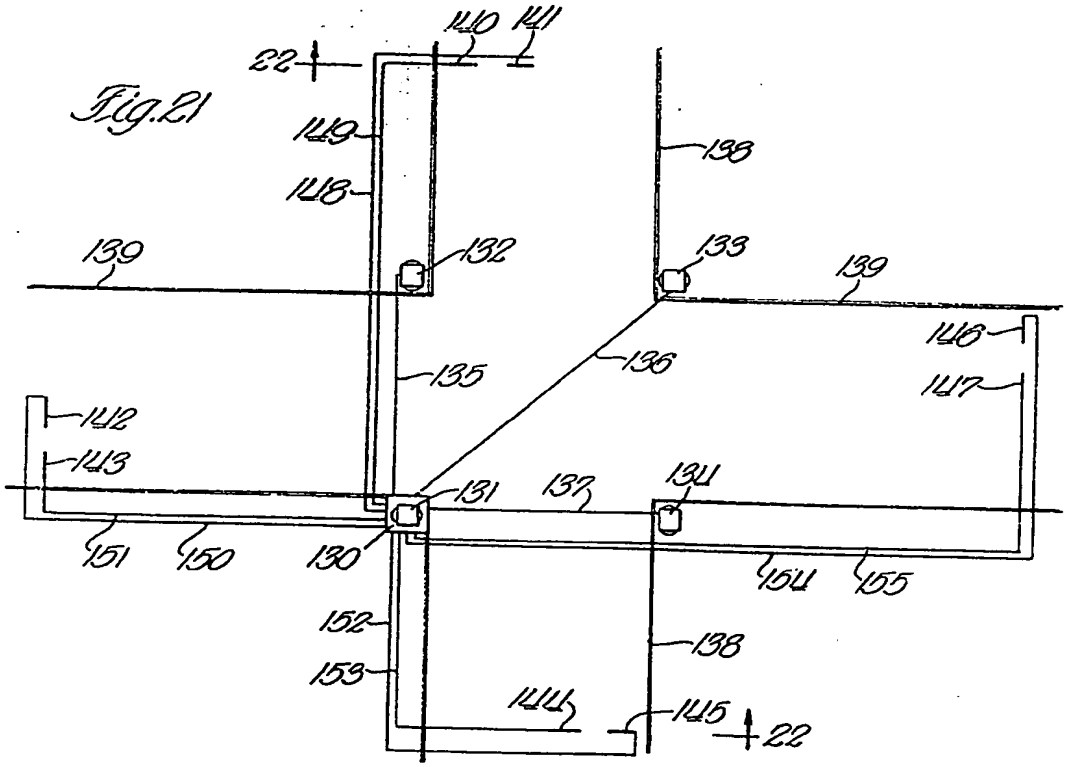
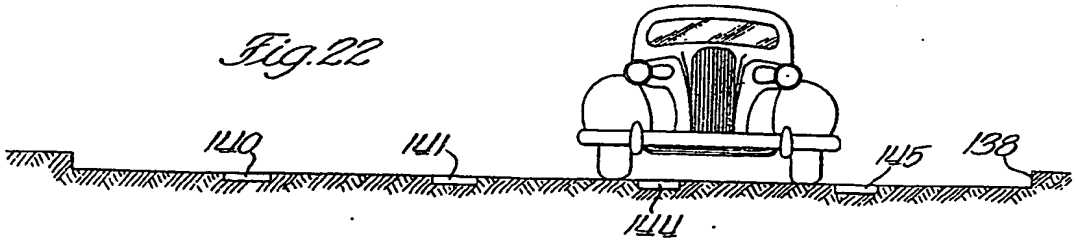
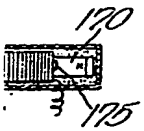


Fig. 22





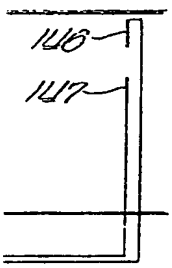


Fig. 23

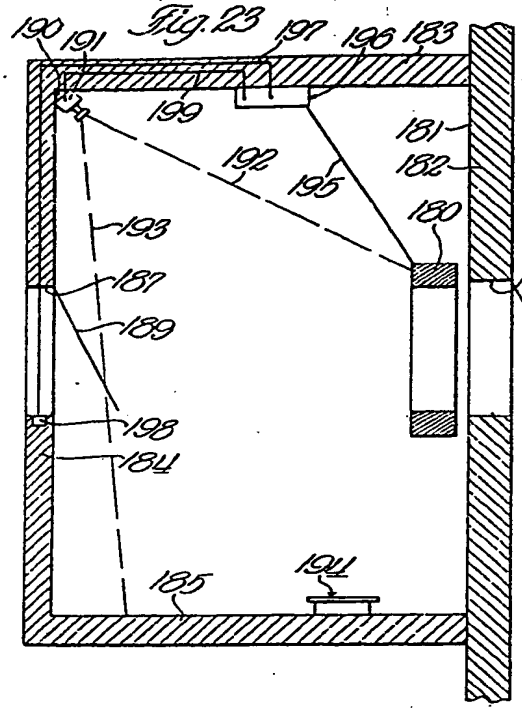


Fig. 24

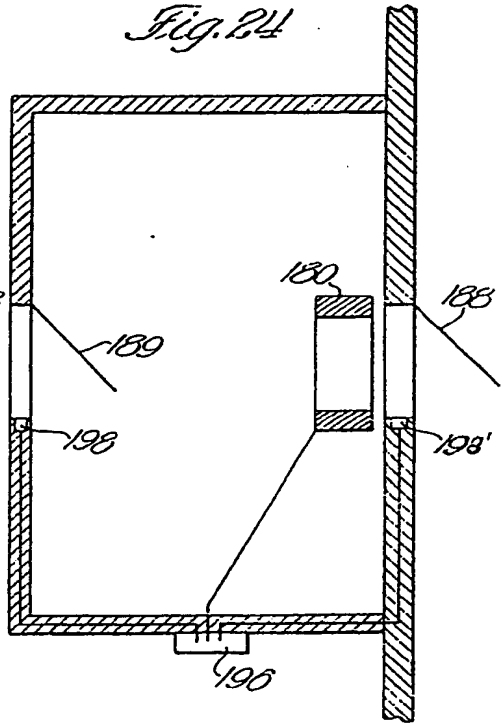


Fig. 25

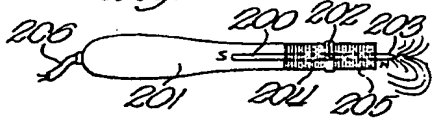


Fig. 26

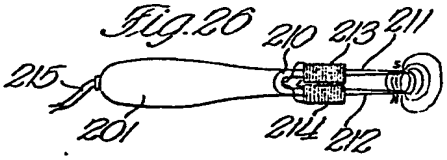
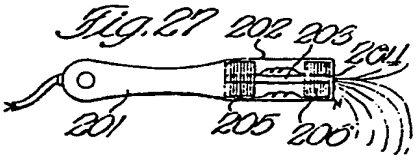


Fig. 27



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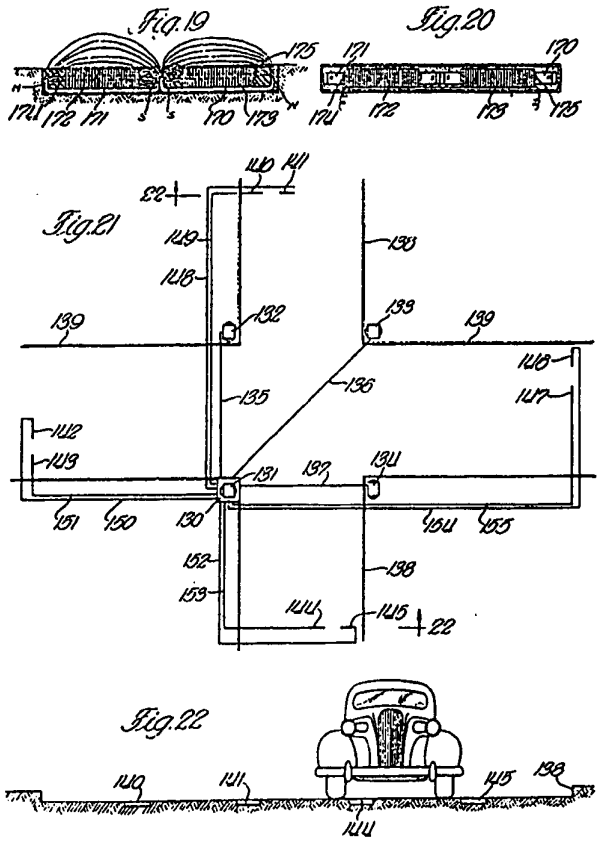
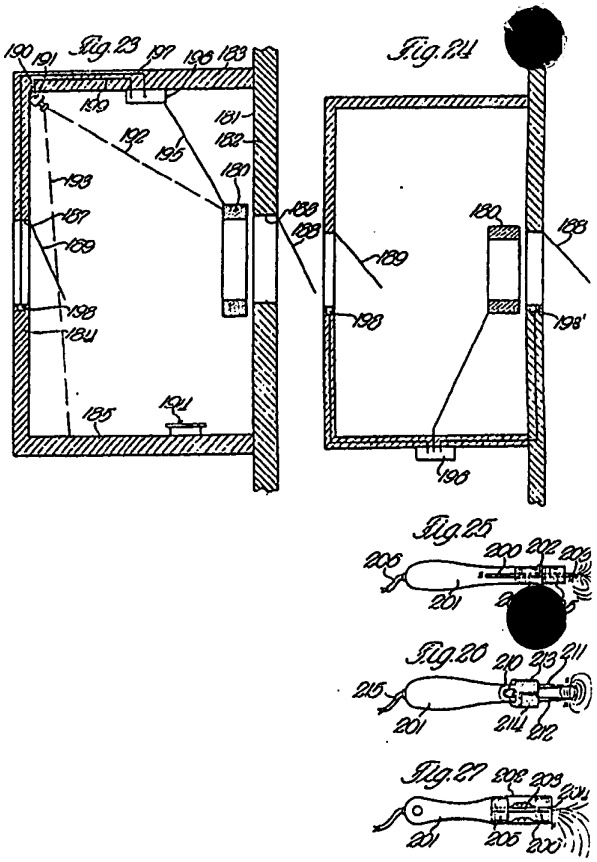
526,805 COMPLETE SPECIFICATION

SHEET 4

[This Drawing is a reproduction of the Original on a reduced scale.]





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